CERFACS

CENTRE EUROPÉEN DE RECHERCHE ET DE FORMATION AVANCÉE EN CALCUL SCIENTIFIQUE

PREFACE

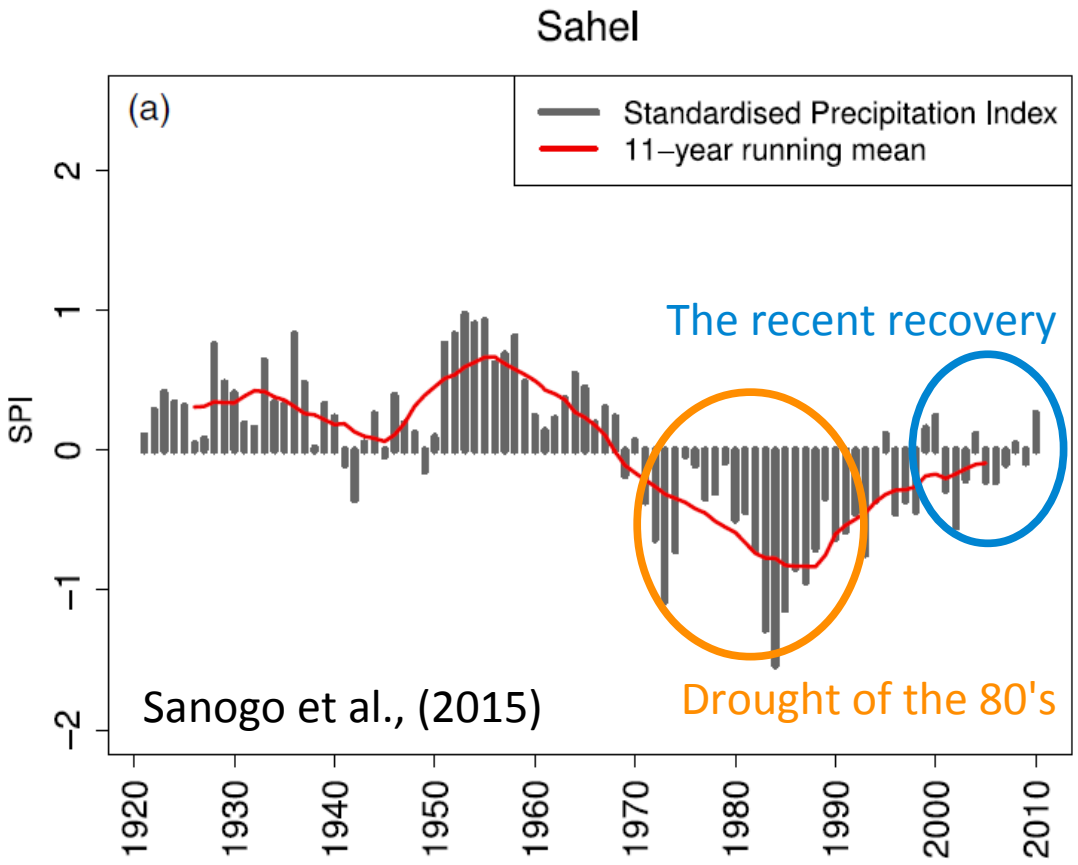
Future Sahelian rainfall projections and selection of a sub-ensemble of CMIP5 models for impact studies

Monerie Paul-Arthur, Sanchez-Gomez Emilia, Boé Julien
CERFACS/CNRS

PREFACE general assembly – August 2015, Cape Town

cnrs dépasser les frontières

The recent rainfall recovery in West Africa



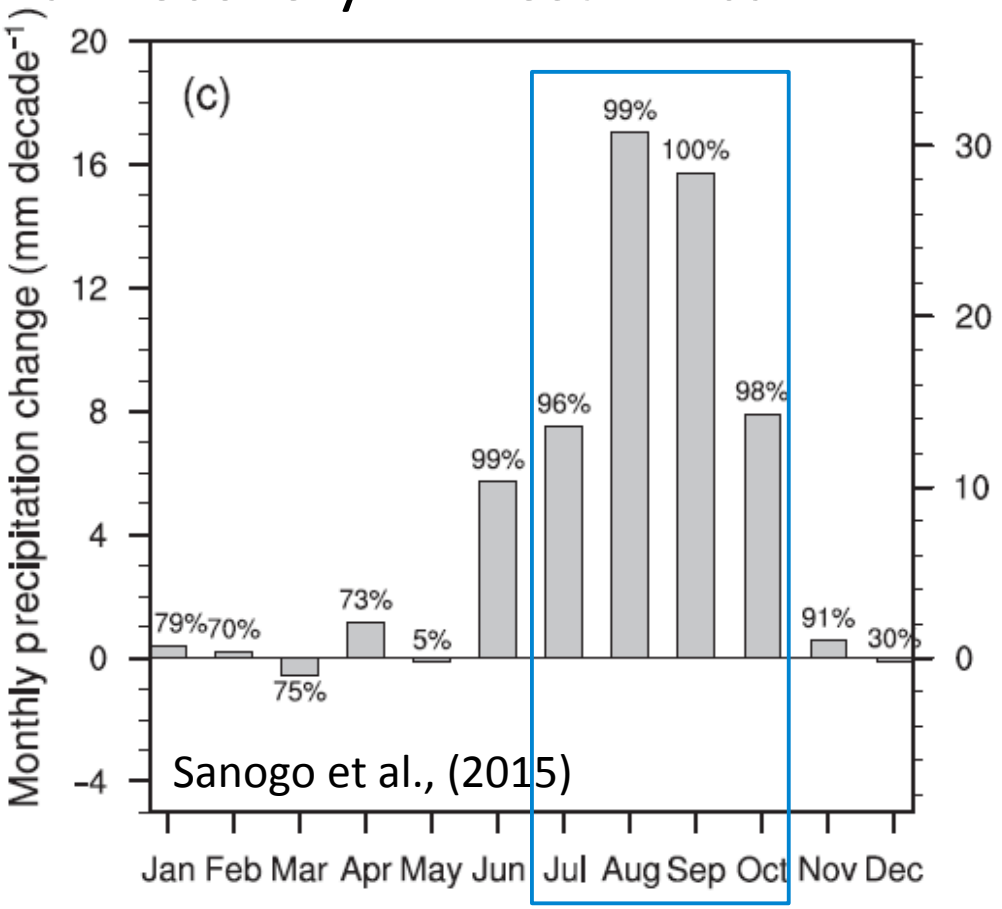
The Standardised Precipitation Index (SPI) and its 11-year running mean, between 1921 and 2010.

Introduction

The recent rainfall recovery in West Africa

The August-October period exhibits the largest rainfall recovery in the Sahel.

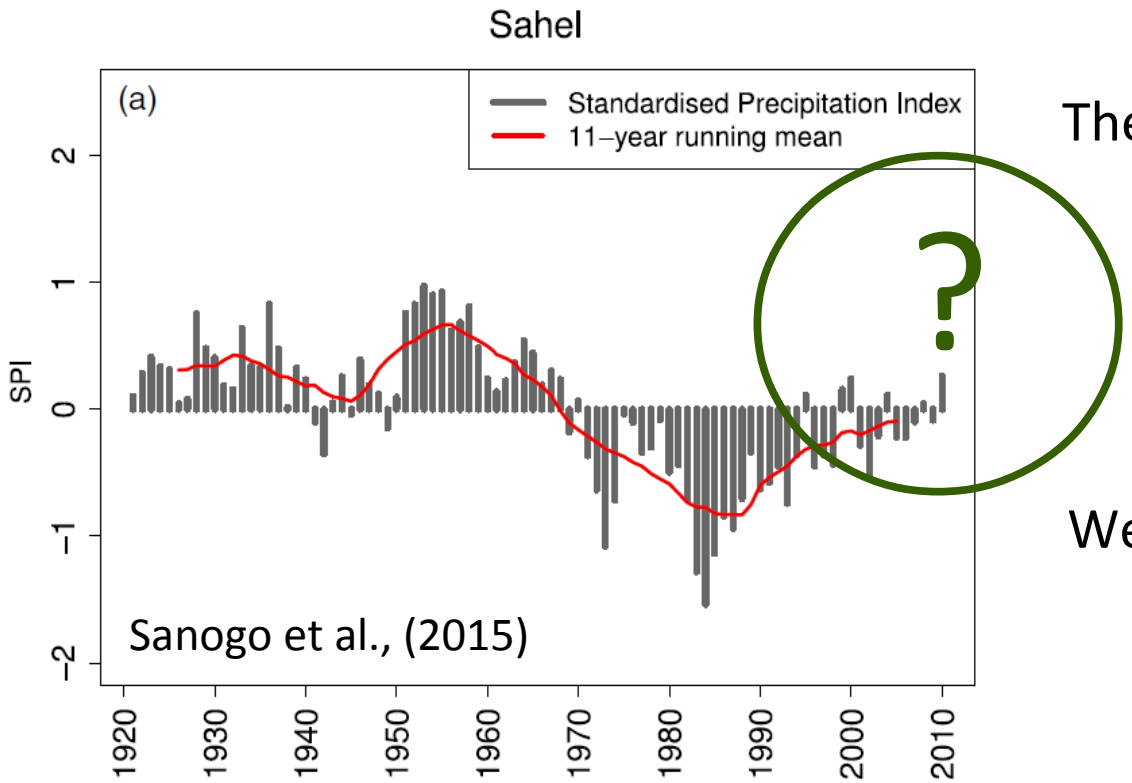
The date of the retreat of the rainy season significantly moved later.



The monthly rainfall trends (in mm decade-1; left axis) and their percentage contribution to the annual trends (in%, right axis). 1980-2010.

Introduction

In the future ?



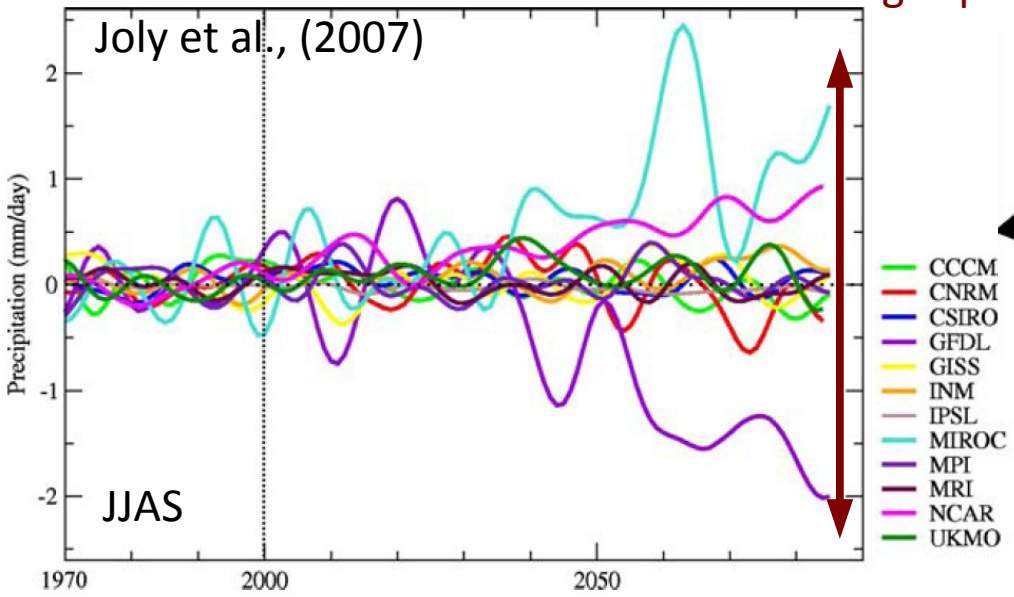
The recovery is associated with the increase in GHGs (Dong and Sutton, 2015).

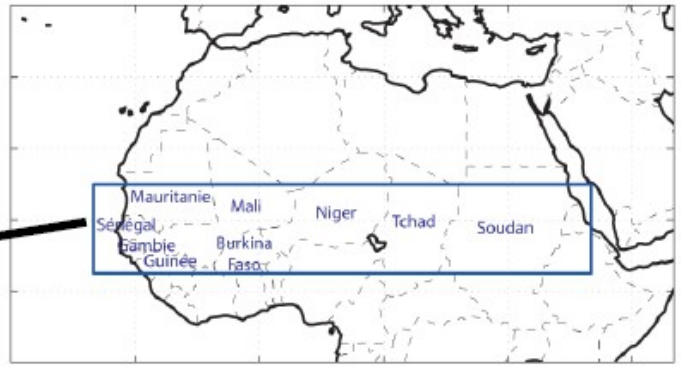
We may thus expect an increase in rainfall in the future.

Introduction

CMIP3 models

Joly et al., (2007)





The west African monsoon projections remain however uncertain due to a large inter-model spread

Is this due to the model biases ?
or to the considered period or/and domain ?

Aims of this study

- What are the main Sahel rainfall responses in CMIP5 models ?

- Is there any relationship between the model response regarding to global warming and the mean model biases ?

- Can we define a sub-ensemble of models, representative of the uncertainty generated by the models from CMIP5 ?

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Data and methodology

32 CMIP5 models, interpolated into the same 2.5°x2.5°resolution

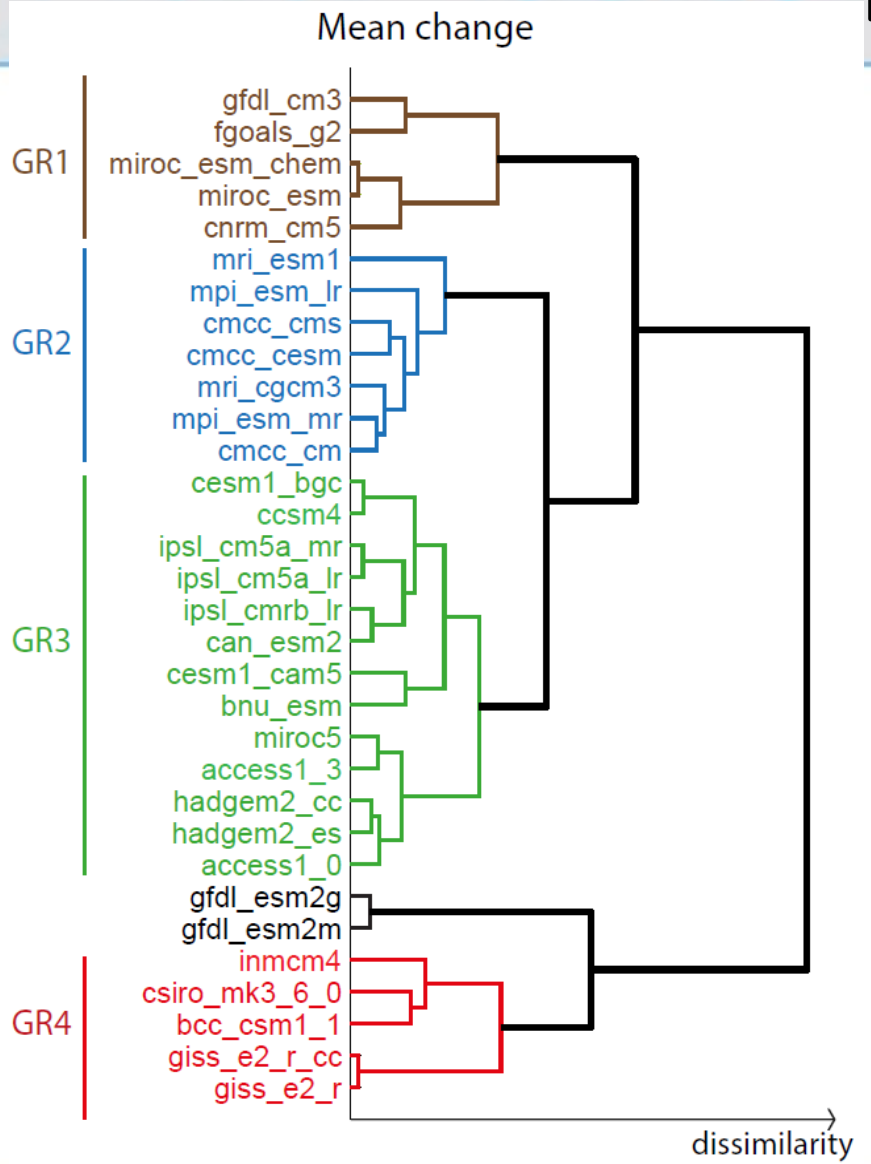
CTRL period : 1960-1999 using the historical scenario
FTR period : 2060-2099 under the rcp8.5 emission scenario

The climate change impact on the monsoon is evaluated by

$$\Delta pr = prFTR - prCTRL$$

A consensus on the multi-model anomalies is considered as robust when at least 80% of the models agree on the sign of the change.

Data and methodology



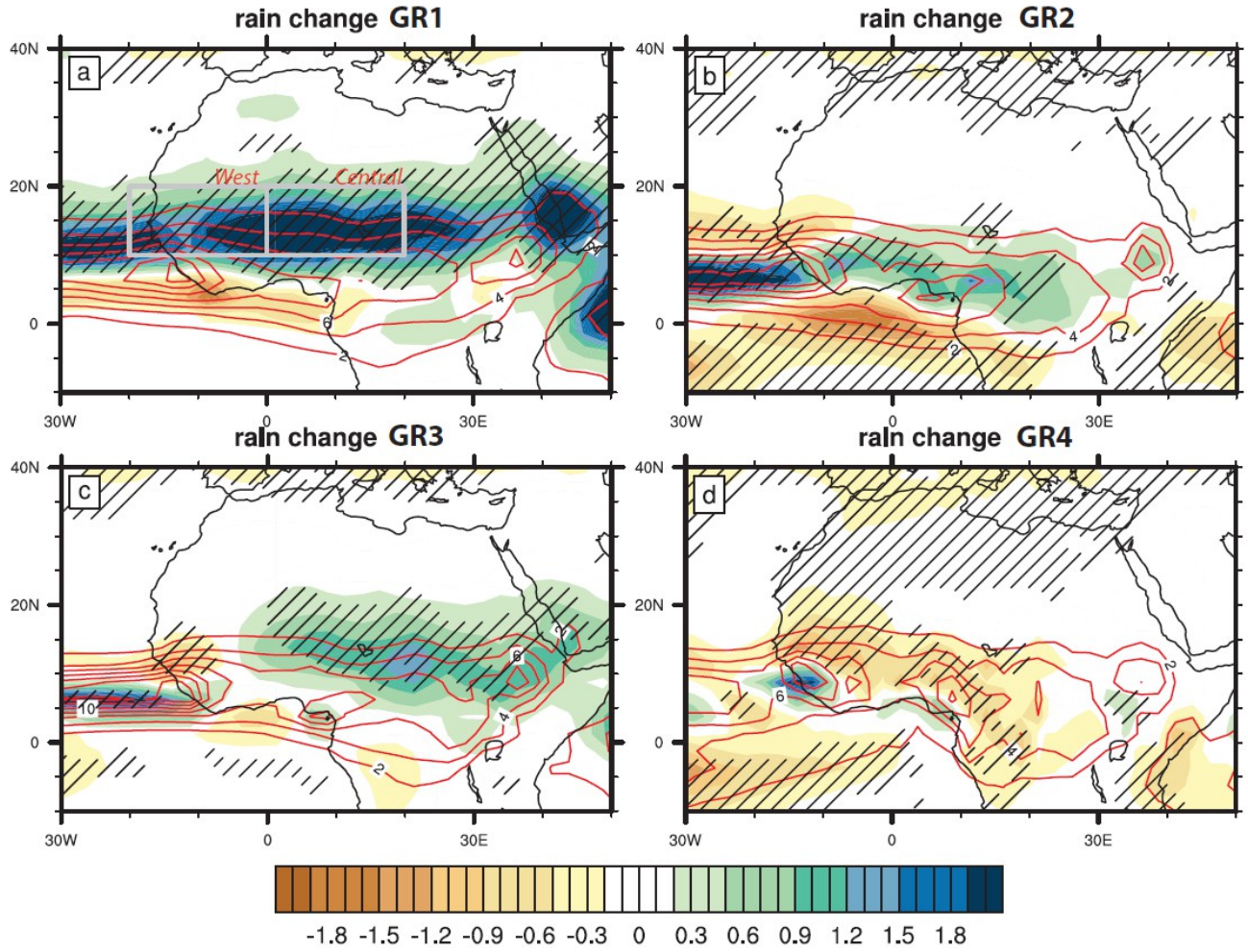
The classification of the models is computed by the pattern correlation of Δpr over the Sahel

Models are classified into 4 groups

The models originating from the same climate centre show close projections

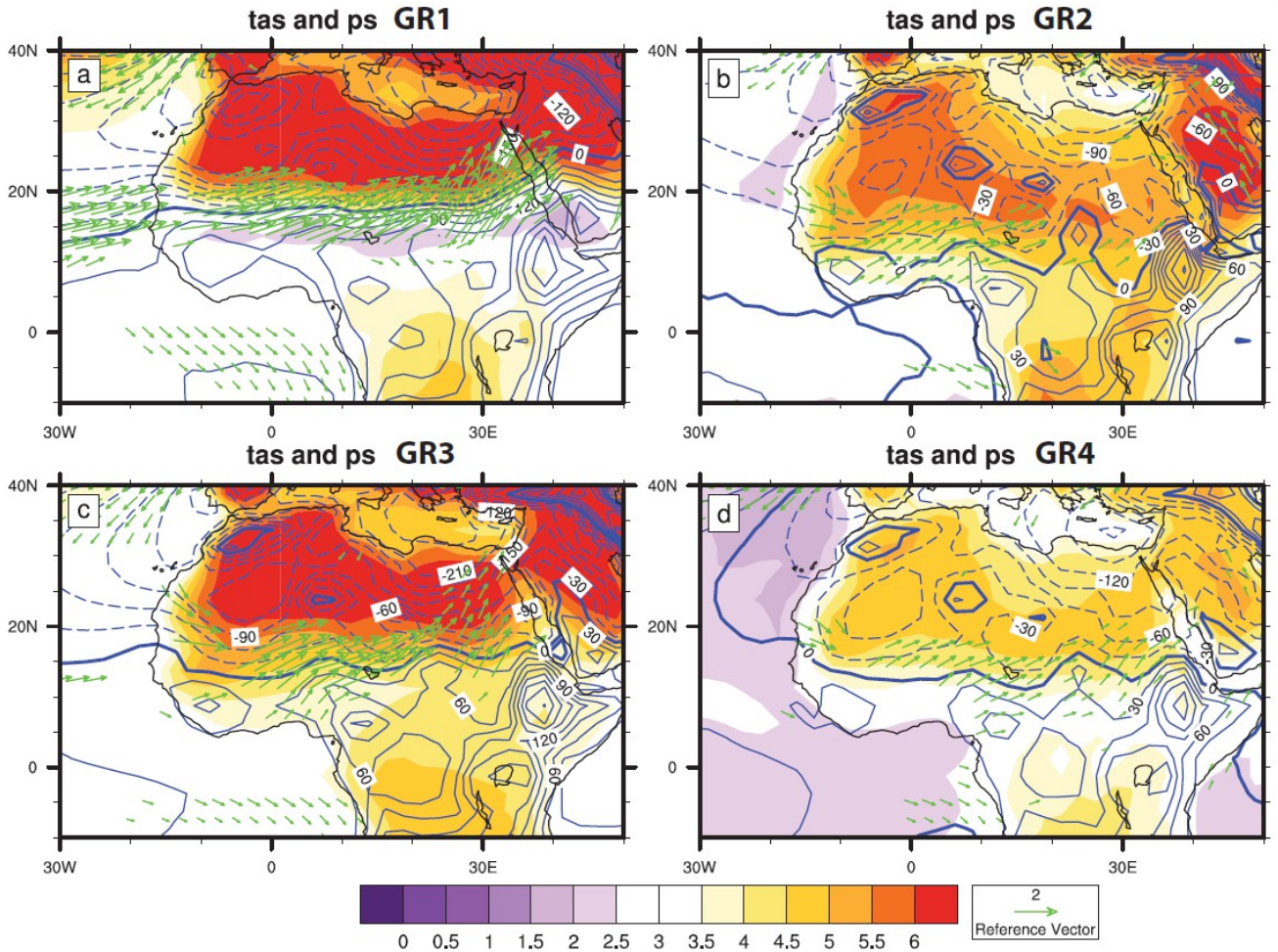
Results : Precipitation change

In JAS



Projected changes in JAS for (a-d) precipitation (mm.day-1). Hatching represents the grid-points where at least 80% of the models agree with the ensemble mean computed from all the available models.

Results : tas, ps and wind changes



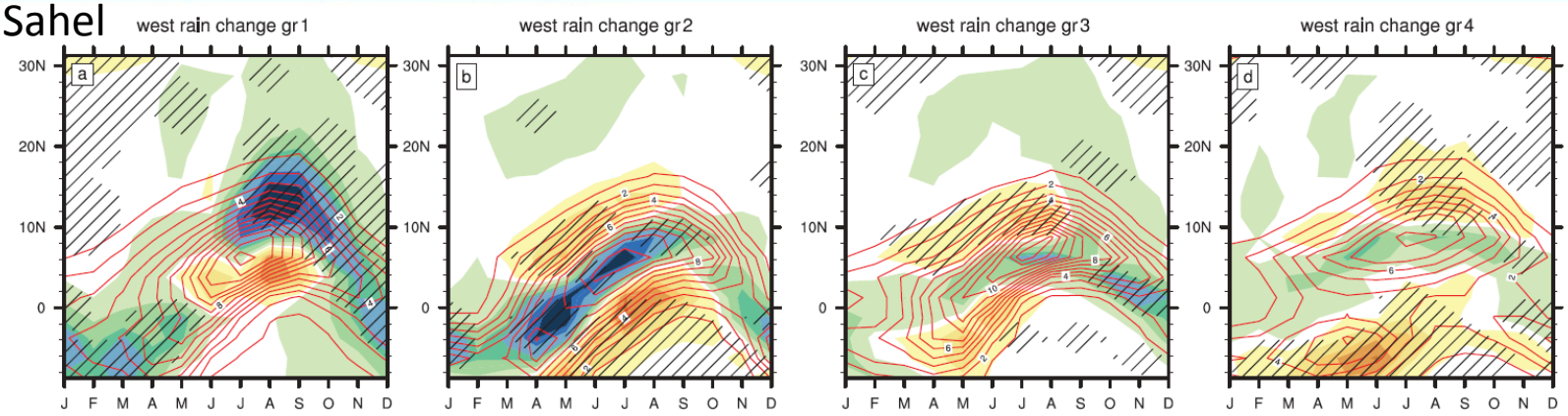
The 4 groups of models project a strengthening of the gradient of temperature between the Sahara and the Gulf of guinea

GR1 and GR3 project a warmer Saharan desert than GR2 and GR4 along with an increase in precipitation.

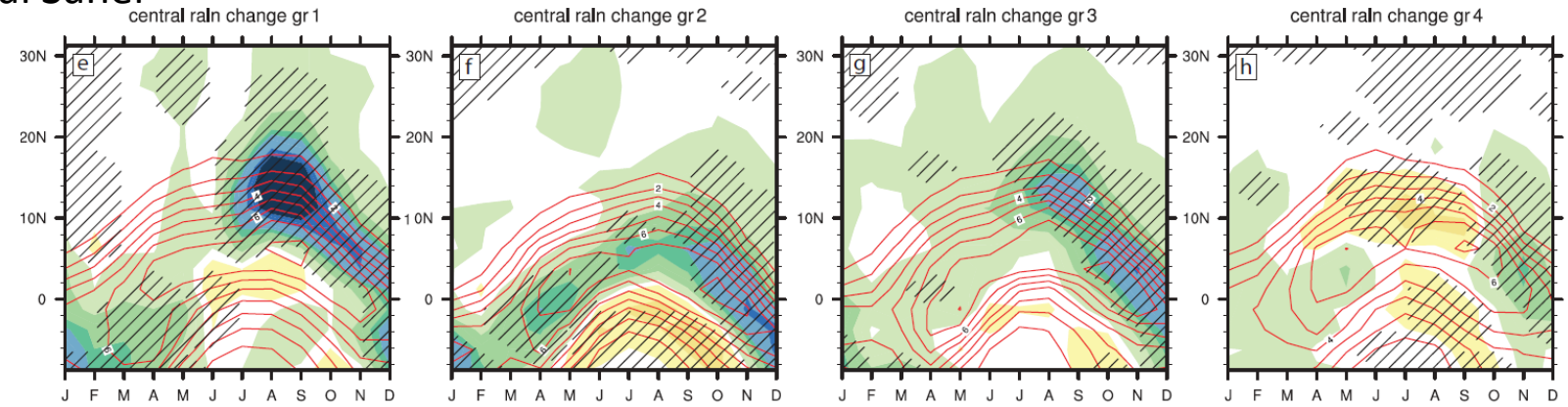
Projected changes for (a-d) 2m temperature (°C) (shading), sea level pressure (hPa) (blue contours) and 950 hPa winds (m.s-1) (green arrows). The winds anomalies are displayed if at least 80% of the models agree on the signals. Hatching represents the grid-points where at least 80% of the models agree with the ensemble mean computed from all the available models

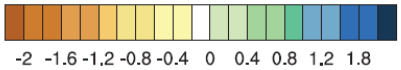
Results : Seasonal cycle

West Sahel



Central Sahel

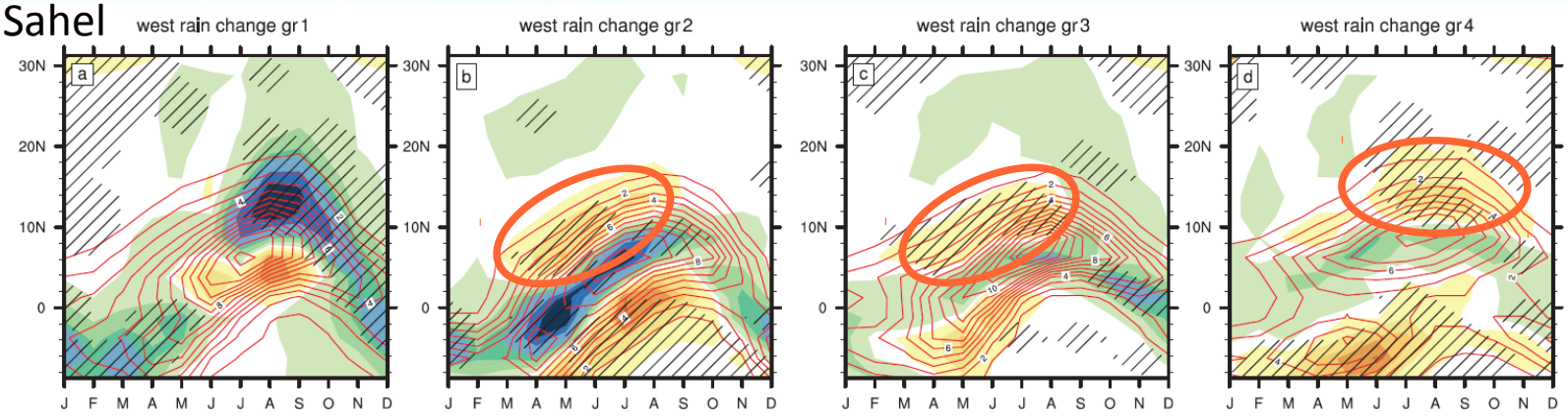




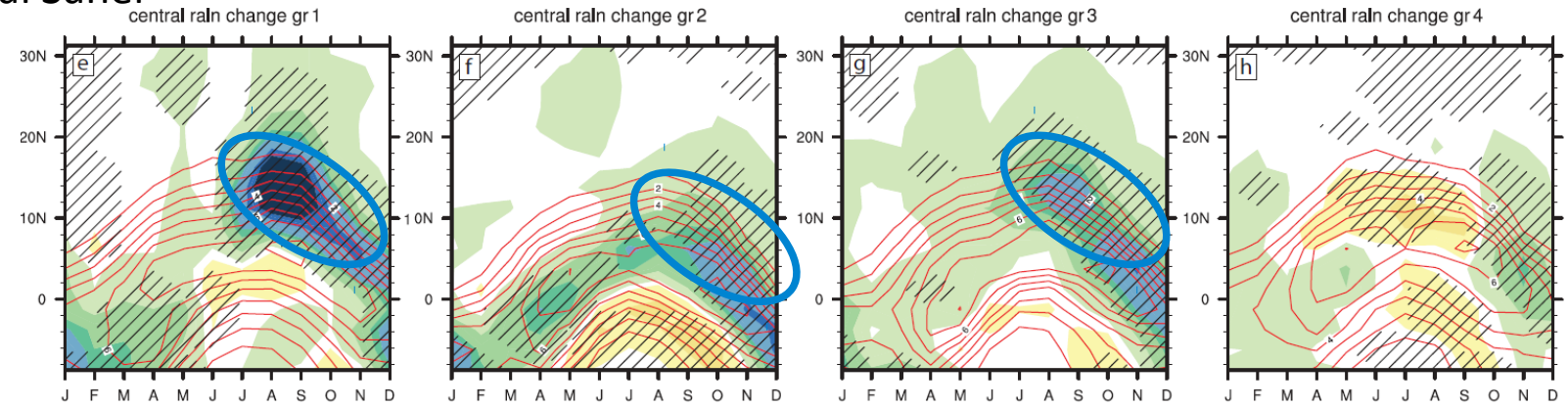
Time-Latitude diagram from January to December and averaged from (a-d) 20°West to 0° of projected and 0° to 20°East (e-h) rainfall amounts (mm.day-1). The monthly mean CTRL climate is displayed with red contours and the FTR-CTRL anomalies in colors. The hatching represents the grid-points where at least 80% of the models are agreed with the ensemble mean FTR-CTRL change.

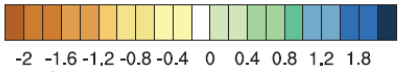
Results : Seasonal cycle

West Sahel



Central Sahel

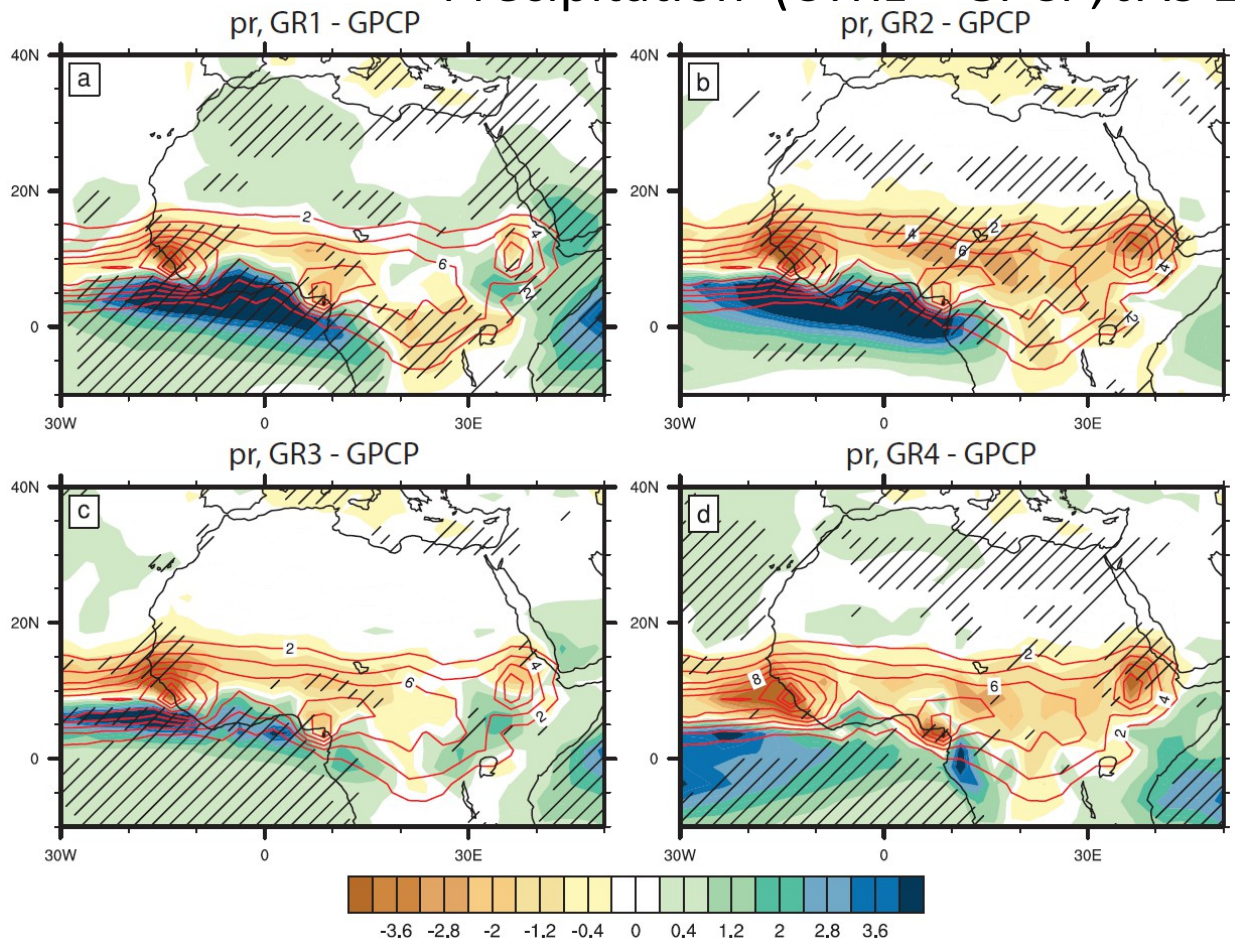




3 groups of models simulate a decrease (increase) in precipitation over the Western (central) Sahel → not homogeneous

Results : Biases-projection relationship

Precipitation (CTRL – GPCP; JAS 1979-1999)



Mean bias of (a-d) rainfall amounts (model output minus GPCP; mm.day-1) in color and mean JAS precipitation of GPCP (red lines). The hatching represents the grid-points where at least 80% of the models are agreed with the sign of the bias.

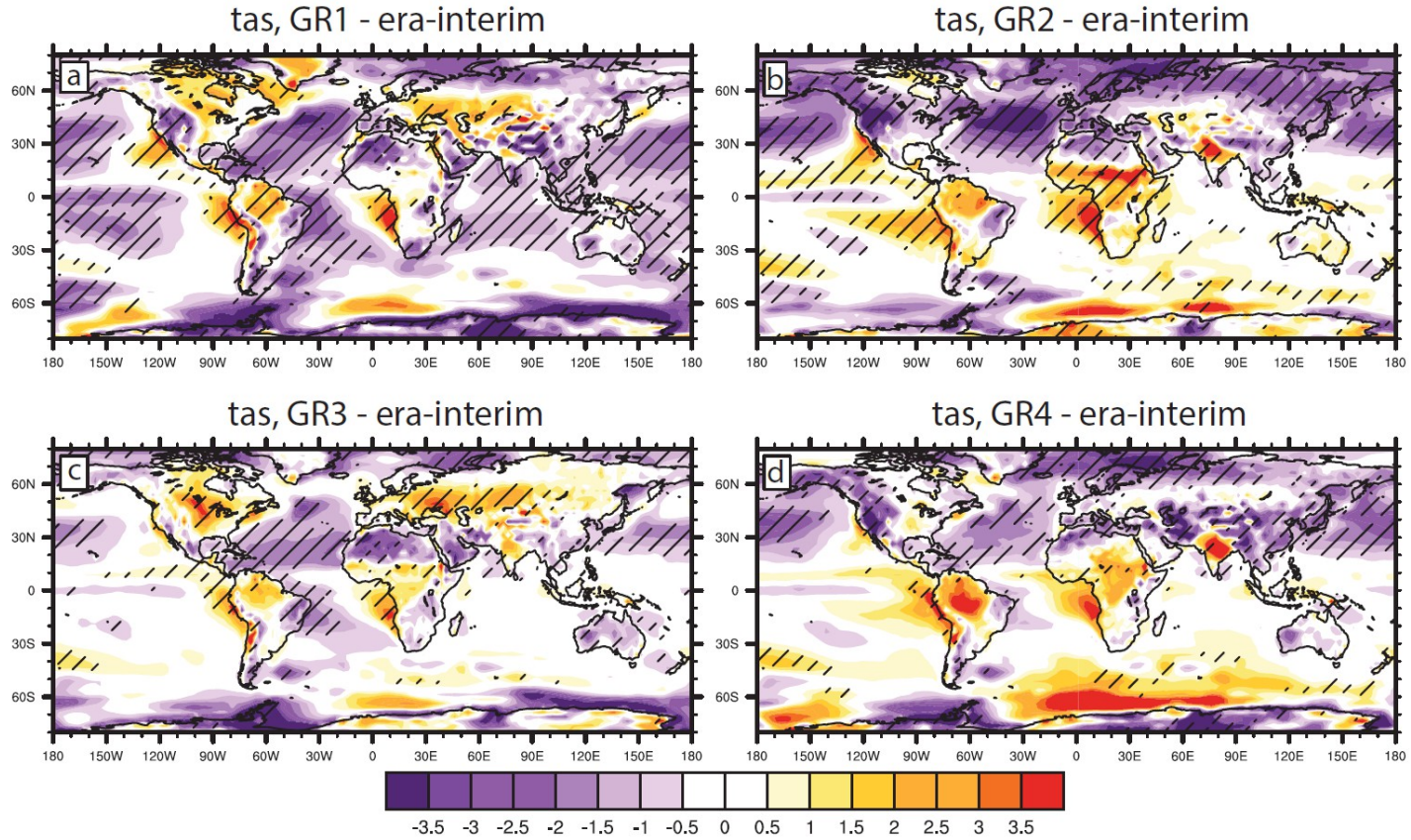
Same pattern of bias in precipitation:

- Wet biases over the gulf of Guinea
- Dry biases of the Sahel

→ The monsoon system is located too southward

Results : Biases-projection relationship

Surface-air temperature (CTRL – era-interim; JAS 1979-1999)



Mean bias of (a-d) surface-air temperature (model outputs minus era-interim, °C) in color and mean JAS temperature of era-interim (red lines). The hatching represents the grid-points where at least 80% of the models are agreed with the sign of the bias.

Same pattern of bias in Temperature :

- Cold biases over the North Atlantic the Saharan desert.

- Warm biases over the Tropical Atlantic.

Results : the model selection

- There is no relationship between the mean biases and the projections

-> The model selection is thus performed on δpr

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The aim is to define a sub-ensemble of models, which is representative of the uncertainty generated by the whole ensemble of CMIP5 models

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3 methods are proposed

"non-a-priori" method

Randomly selection of 4 models in the CMIP5 data-set

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"non-a-priori" method	"pattern" method
Randomly selection of 4 models in the CMIP5 data-set	Random selection of 4 models in GR3

Results : the model selection

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"non-a-priori" method	"pattern" method	"diversity" method
Randomly selection of 4 models in the CMIP5 data-set	Random selection of 4 models in GR3	Random select of 1 model per group of models

Results : the model selection

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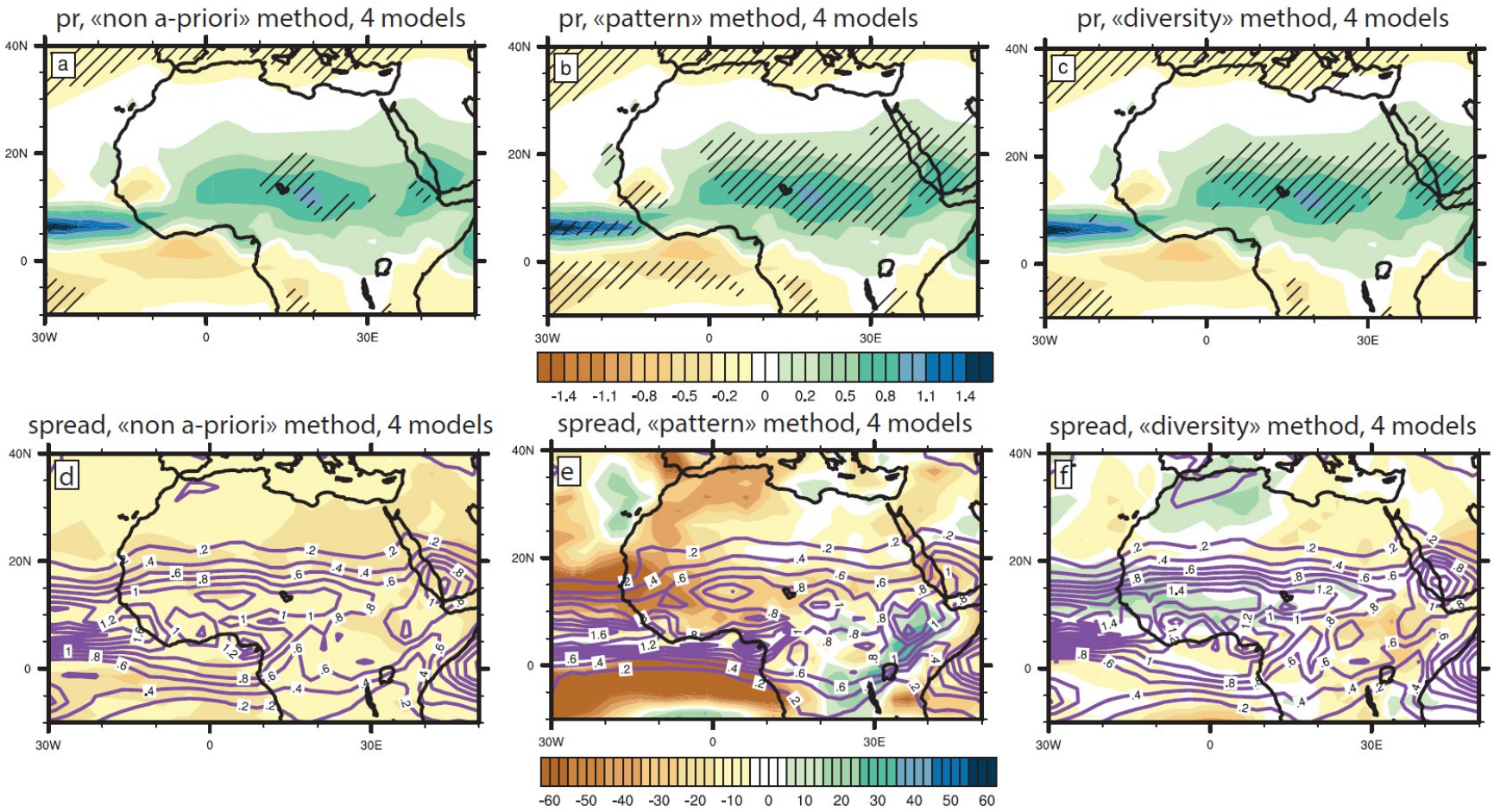
3 methods are proposed

"non-a-priori" method	"pattern" method	"diversity" method
Randomly selection of 4 models in the CMIP5 data-set	Random selection of 4 models in GR3	Random select of 1 model per group of models

The operation is repeated 30 000 times using a Monte-Carlo approach

Results : the model selection



(a-c) Mean FTR-CTRL rainfall changes (mm.day-1) from the 30 CMIP5 models and probability to reproduce it (most-likely when the hatching are added). The probability is computed by a Monte-Carlo procedure and judged most-likely when 95% of the mean FTR-CTRL change of the 30 000 draws is of a same sign as the CMIP5 multi-model change.

Conclusion

- Δpr exhibits a strong spread, ranging from an increase to a decrease in precipitation

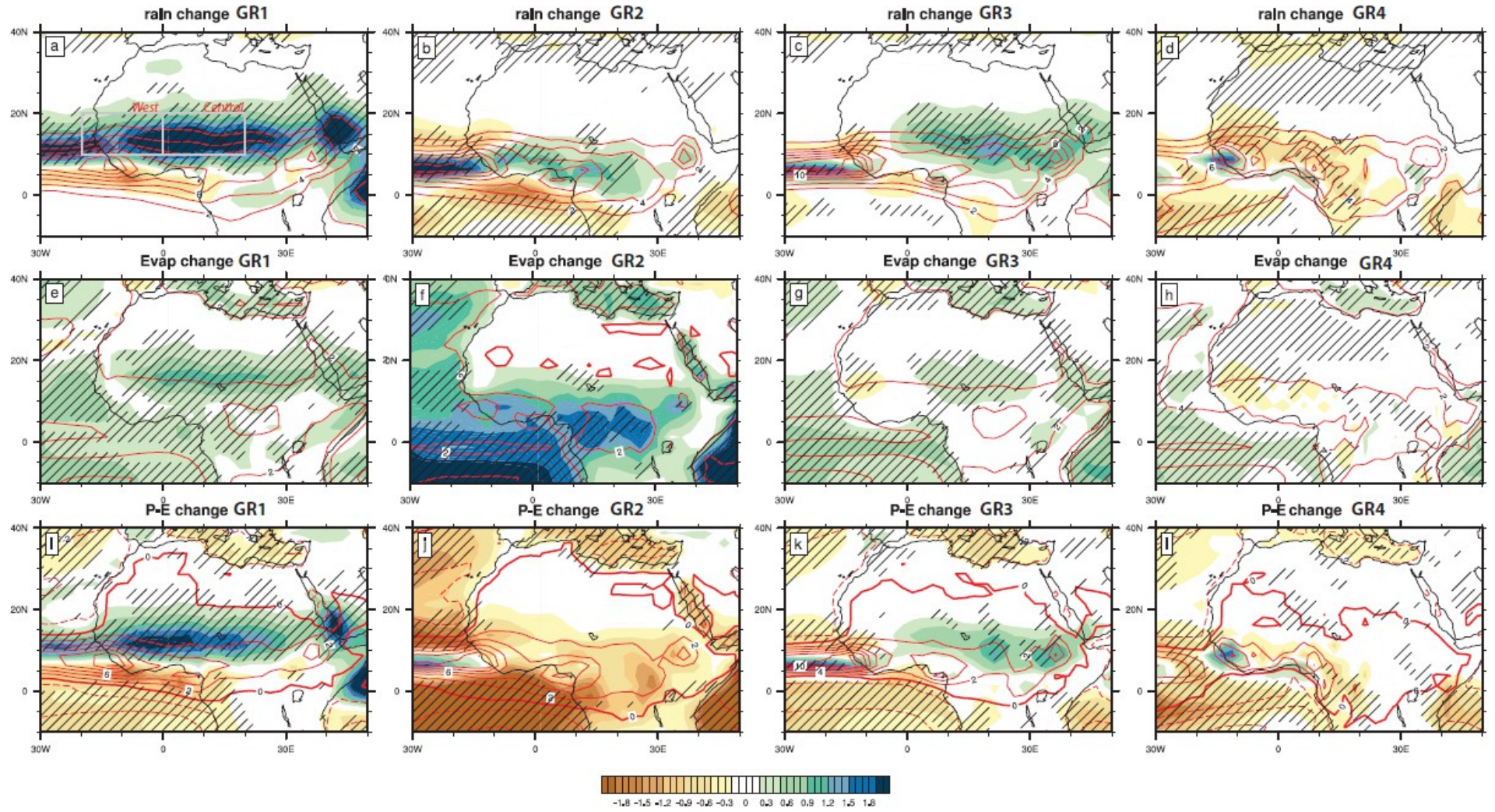
- The increase of rainfall in late monsoon is the most robust projection

- No relationship between the mean biases and the projections

- A methodology is defined in order to use a sub-sample of CMIP5 models for impact studies.

Thank you for your attention

Annexe



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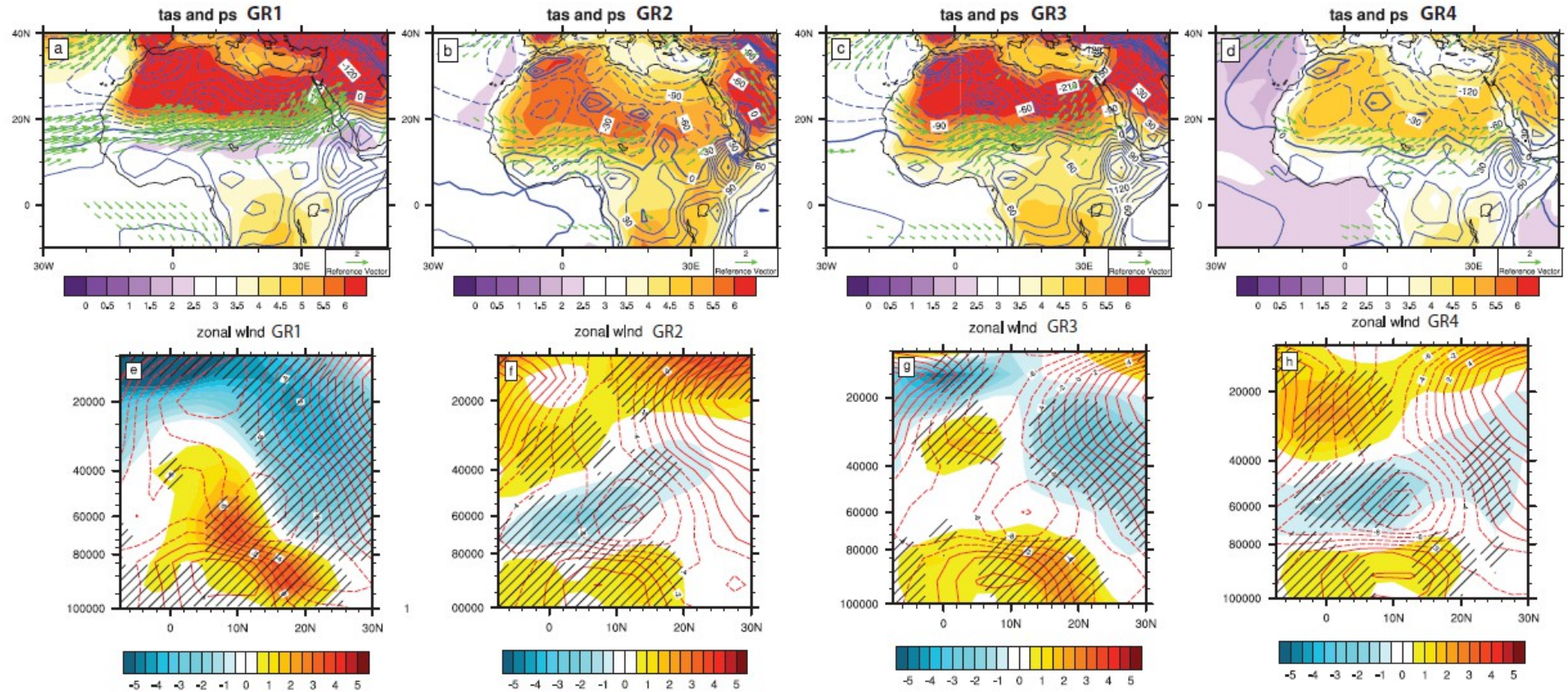
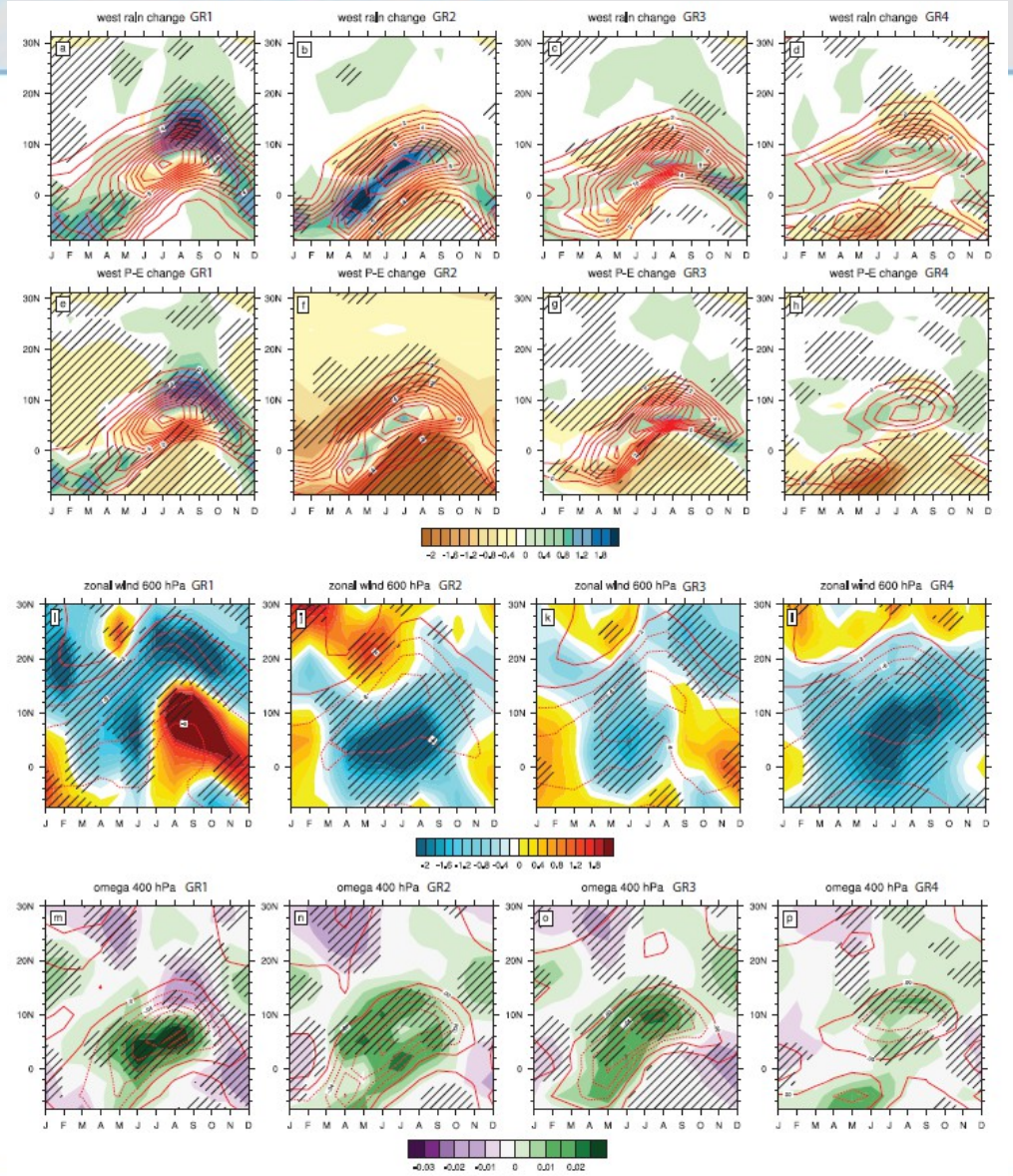
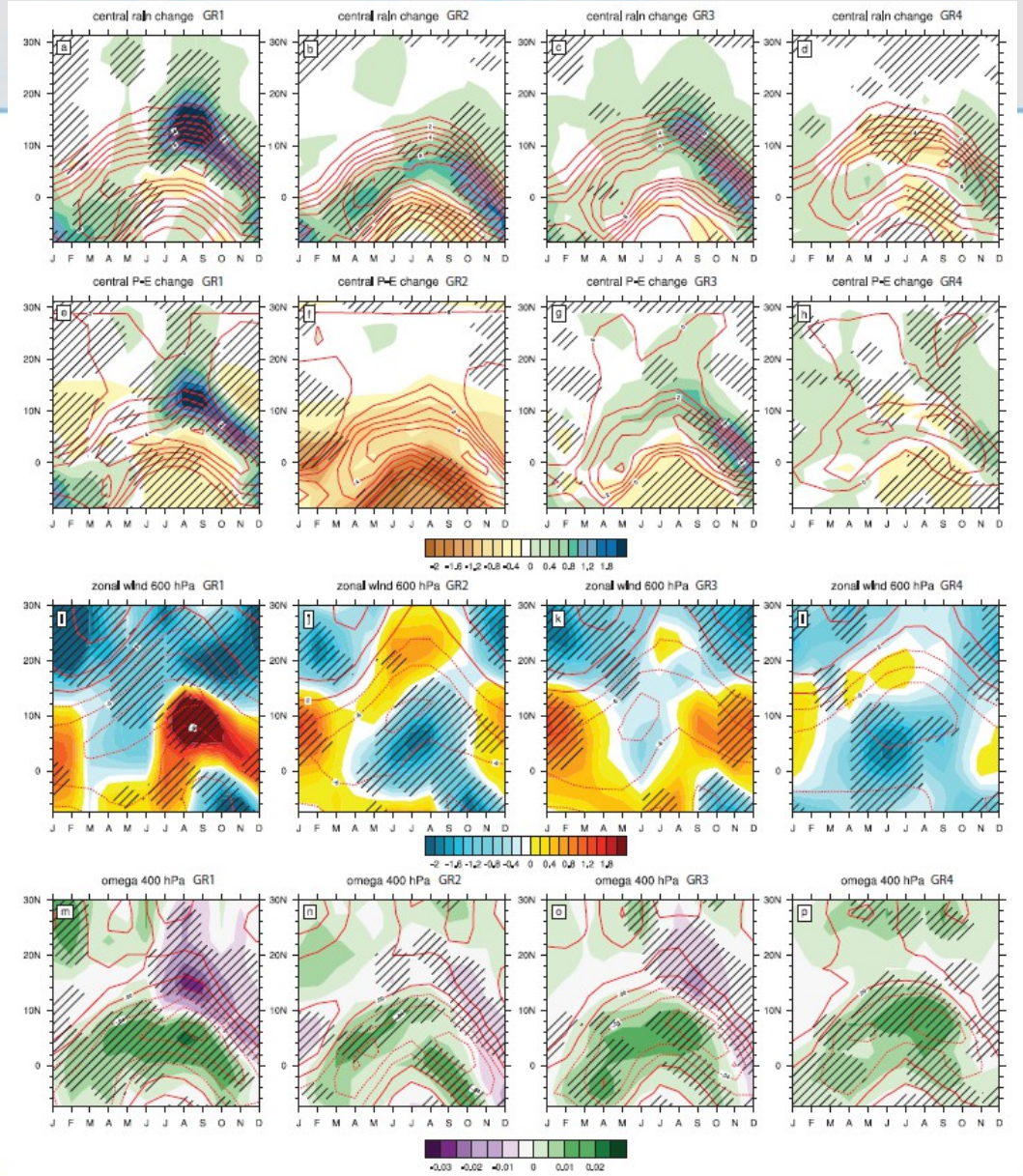
Annexe


tas and ps GR1
tas and ps GR2
tas and ps GR3
tas and ps GR4
zonal wind GR1
zonal wind GR2
zonal wind GR3
zonal wind GR4

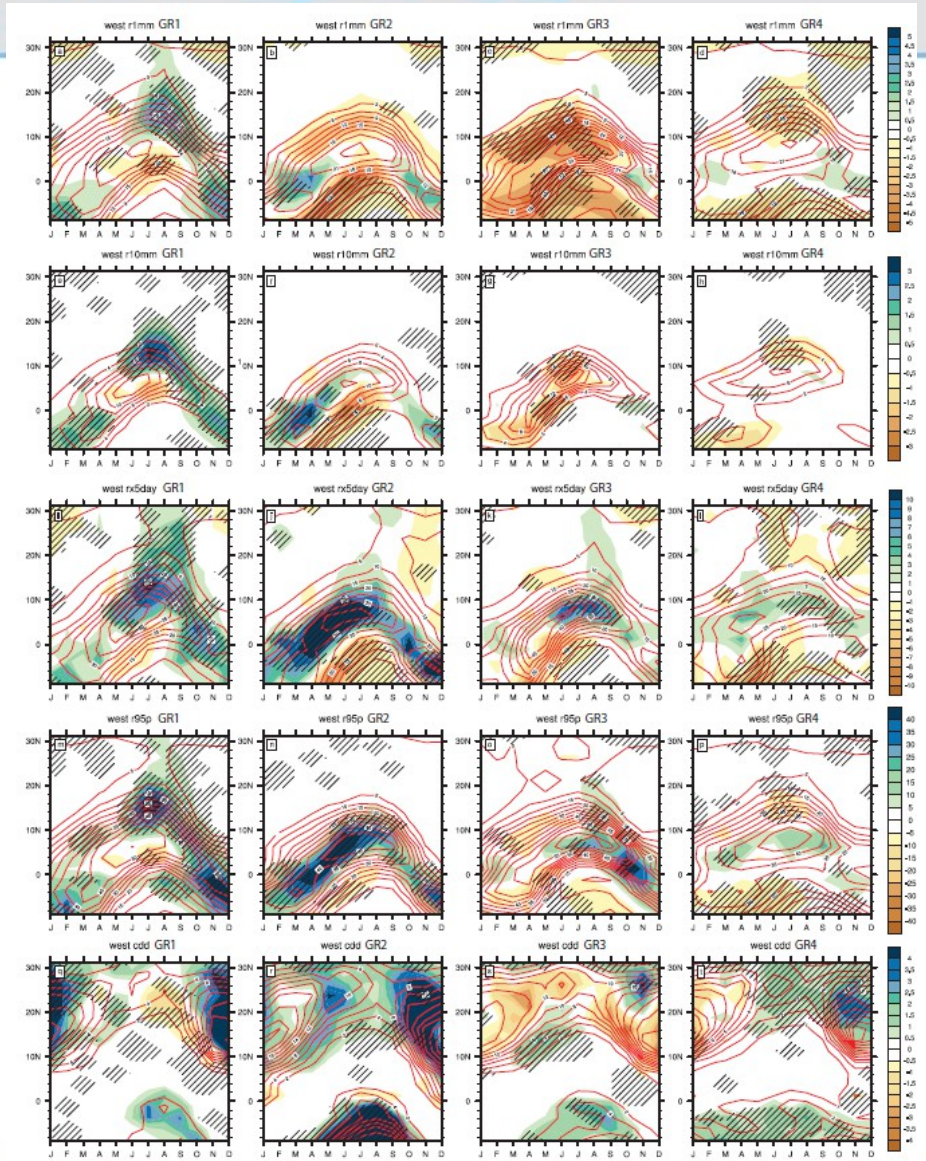
Annexe


west rain change GR1
west rain change GR2
west rain change GR3
west rain change GR4
west P-E change GR1
west P-E change GR2
west P-E change GR3
west P-E change GR4
zonal wind 600 hPa GR1
zonal wind 600 hPa GR2
zonal wind 600 hPa GR3
zonal wind 600 hPa GR4
omega 400 hPa GR1
omega 400 hPa GR2
omega 400 hPa GR3
omega 400 hPa GR4

Annexe


central rain change GR1
central rain change GR2
central rain change GR3
central rain change GR4
central P-E change GR1
central P-E change GR2
central P-E change GR3
central P-E change GR4
zonal wind 600 hPa GR1
zonal wind 600 hPa GR2
zonal wind 600 hPa GR3
zonal wind 600 hPa GR4
omega 400 hPa GR1
omega 400 hPa GR2
omega 400 hPa GR3
omega 400 hPa GR4
J F M A M J J A S O N D
30N
20N
10N
0

Annexe



r1mm

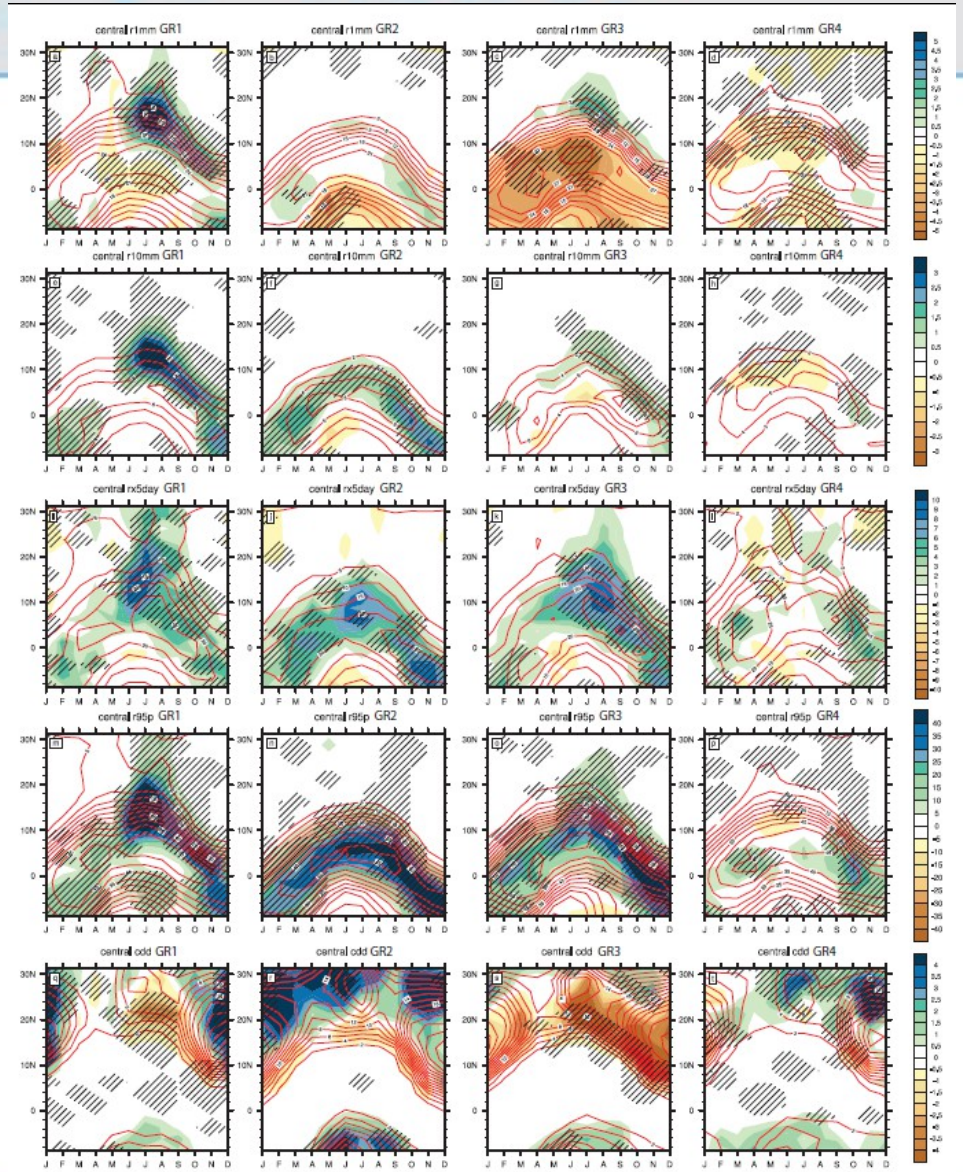
r10mm

rx5day

r95p

cdd

Annexe



r1mm

r10mm

rx5day

r95p

cdd

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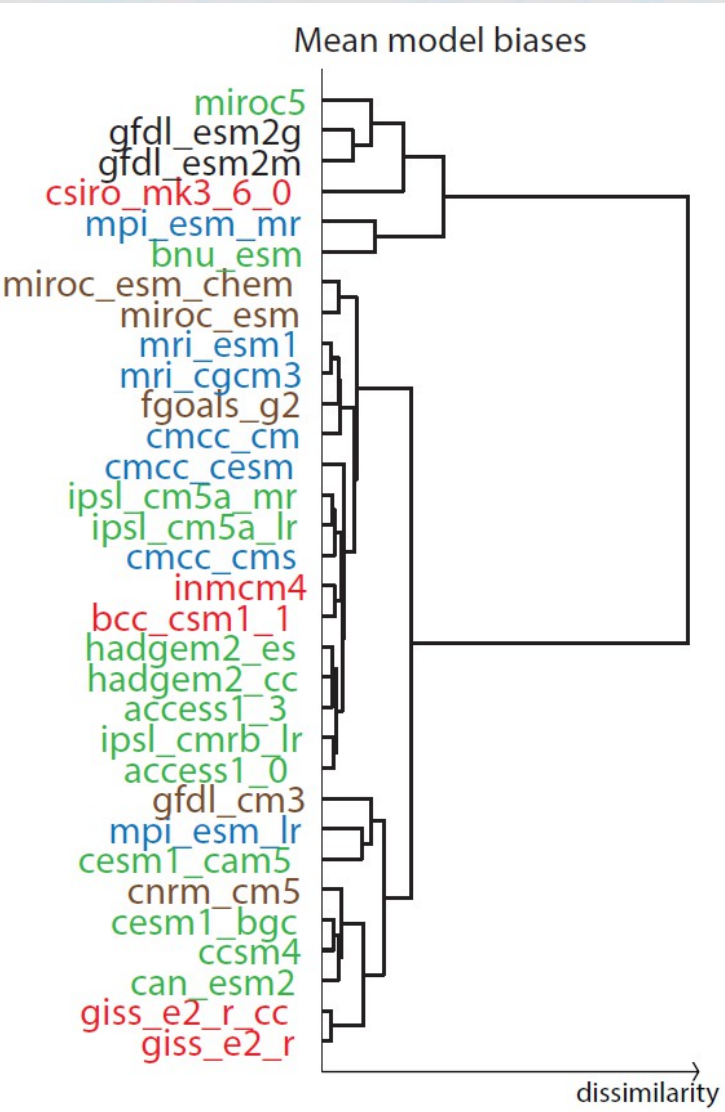
Mean model biases
miroc5
gfdl_esm2g
gfdl_esm2m
csiro_mk3_6_0
mpi_esm_mr
bnu_esm
miroc_esm_chem
miroc_esm
mri_esm1
mri_cgcm3
fgoals_g2
cmcc_cm
cmcc_cesm
ipsl_cm5a_mr
ipsl_cm5a_lr
cmcc_cms
inmcm4
bcc_csm1_1
hadgem2_es
hadgem2_cc
access1_3
ipsl_cmrb_lr
access1_0
gfdl_cm3
mpi_esm_lr
cesm1_cam5
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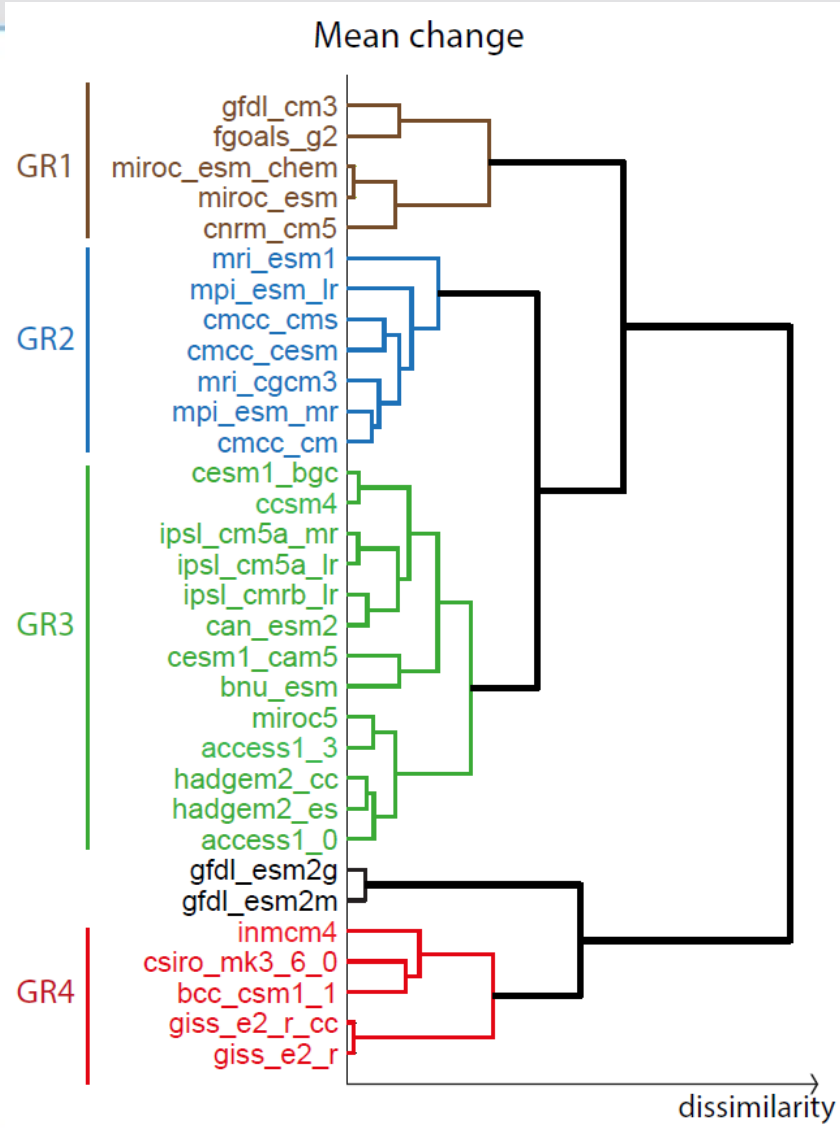
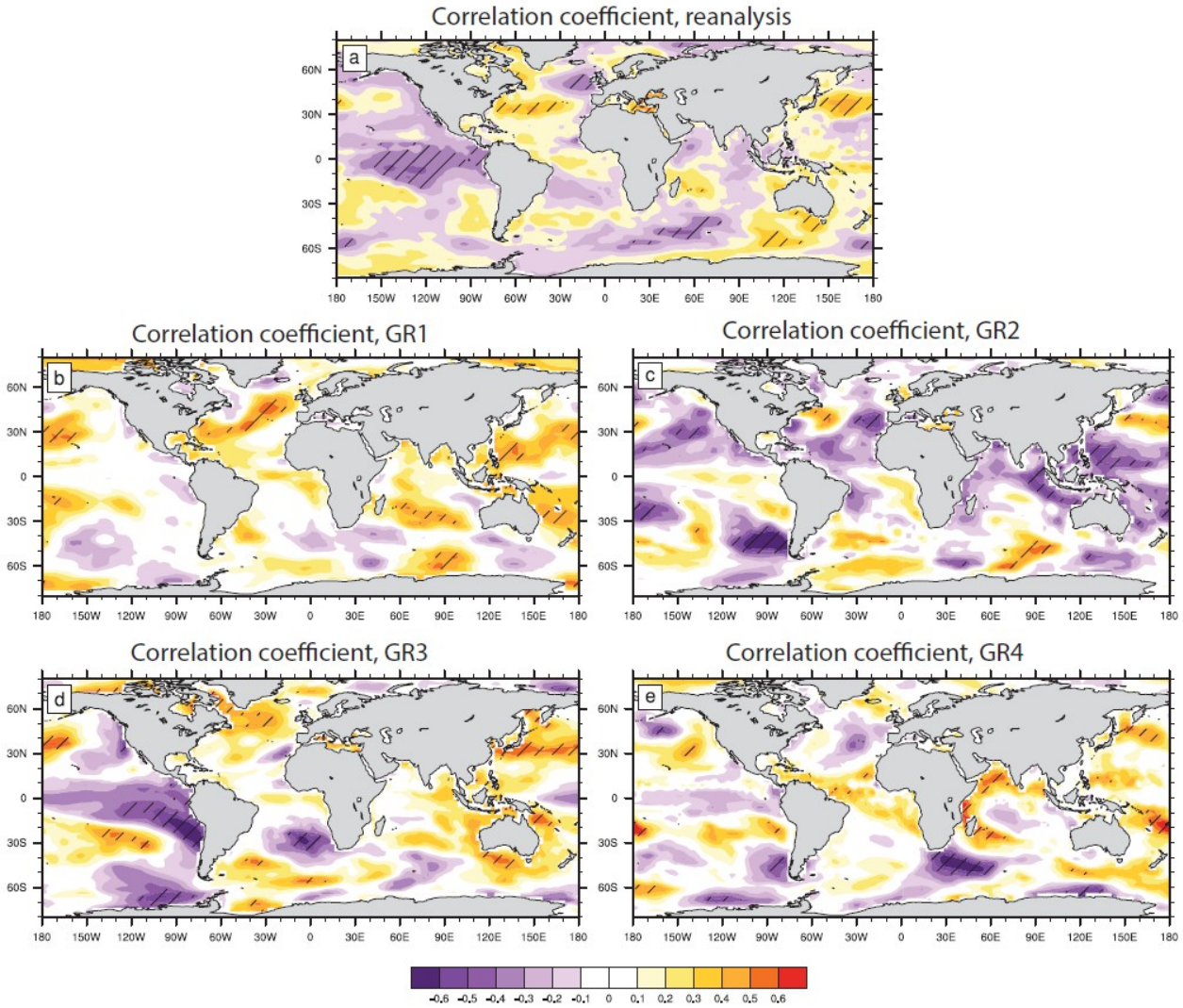
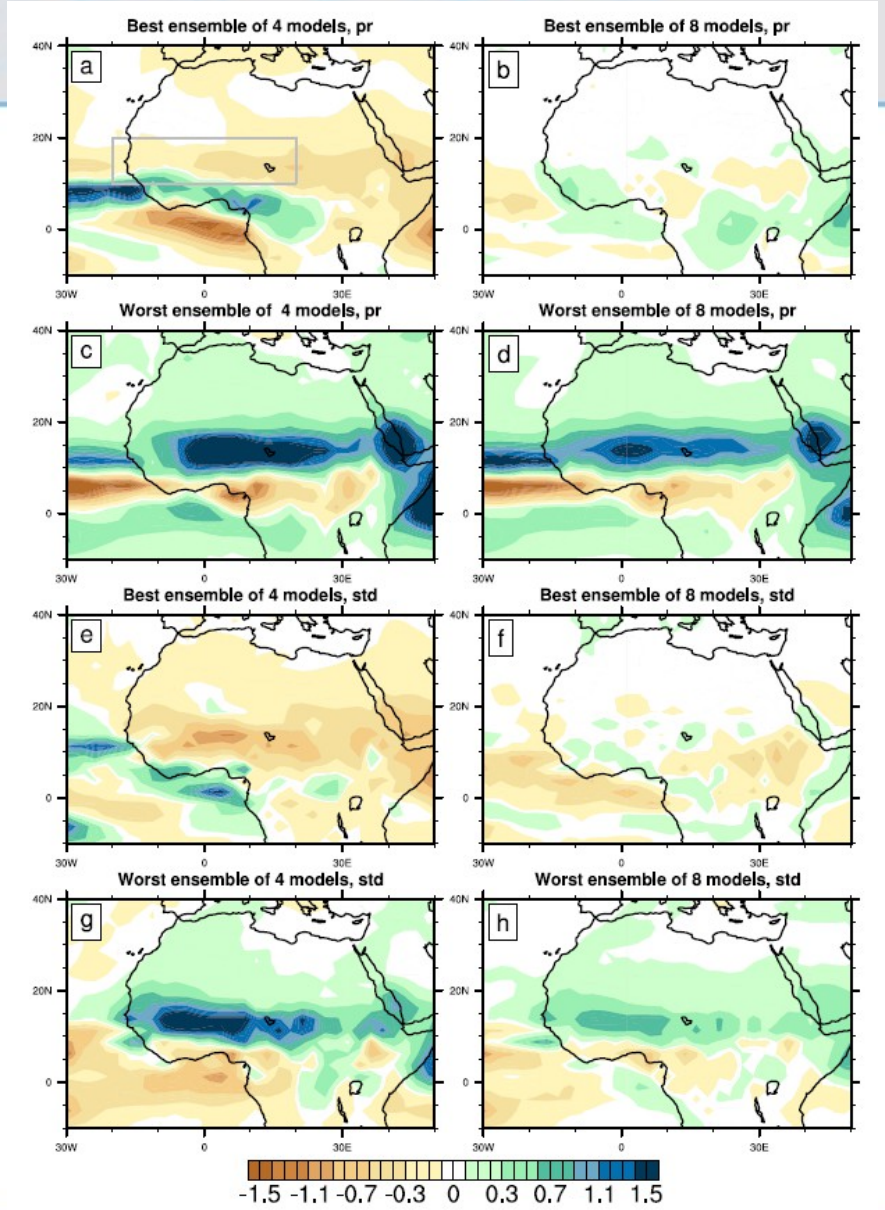
cesm1_bgc
ccsm4
can_esm2
giss_e2_r_cc
giss_e2_r
dissimilarity


Mean change
GR1
GR2
GR3
GR4
gfdl_cm3
fgoals_g2
miroc_esm_chem
miroc_esm
cnrm_cm5
mri_esm1
mpi_esm_lr
cmcc_cms
cmcc_cesm
mri_cgcm3
mpi_esm_mr
cmcc_cm
cesm1_bgc
ccsm4
ipsl_cm5a_mr
ipsl_cm5a_lr
ipsl_cmrb_lr
can_esm2
cesm1_cam5
bnu_esm
miroc5
access1_3
hadgem2_cc
hadgem2_es
access1_0
gfdl_esm2g
gfdl_esm2m
inmcm4
csiro_mk3_6_0
bcc_csm1_1
giss_e2_r_cc
giss_e2_r
dissimilarity

Annexe


Correlation coefficient, reanalysis
a
Correlation coefficient, GR1
b
Correlation coefficient, GR2
c
Correlation coefficient, GR3
d
Correlation coefficient, GR4
e
60N
30N
0
30S
60S
180 150W 120W 90W 60W 30W 0 30E 60E 90E 120E 150E 180
-0.6 -0.5 -0.4 -0.3 -0.2 -0.1 0 0.1 0.2 0.3 0.4 0.5 0.6

Annexe


Best ensemble of 4 models, pr
Best ensemble of 8 models, pr
Worst ensemble of 4 models, pr
Worst ensemble of 8 models, pr
Best ensemble of 4 models, std
Best ensemble of 8 models, std
Worst ensemble of 4 models, std
Worst ensemble of 8 models, std
a
b
c
d
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f
g
h
40N
20N
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30W
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30E
-1.5 -1.1 -0.7 -0.3 0 0.3 0.7 1.1 1.5